TECHNICAL MEMORANDUMS

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AERODYNAMIC FORCES AND MOMENTS OF A SEAPLANE ON THE WATER

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I. INTRODUCTION

The designers and pilots of seaplanes should have a thorough knowledge of the action of air and water on floating objects. This is possible only when adequate hydrodynamic and aerodynamic data are at their disposal. The problems involved are so complex that they cannot be solved by theory alone. It is necessary to find the right combination of theory and experimental data. Full-scale tests are not expedient or necessary for a comprehensive systematic investigation. Laboratory research is more suitable. The problem has already been tackled from the experimental hydrodynamic side (reference 1). This report gives the results of wind-tunnel tests with a seaplane model as a contribution to the solution of the aerodynamic problems.

II. TESTS

In the tests it was assumed that the seaplane rested motionless on the water and was exposed, in various positions with respect to the supposedly flat surface of the water, to a uniform air current at 0° to 360°.

1) Model.- The tests were made with the model of a twin-engine seaplane from the Heinkel works in Warnemünde. The biplane cellule had a straight upper wing and a lower wing with a slight dihedral. The two lateral engine nacelles were between the wings. The fuselage and tail surfaces were of the conventional type. The twin floats had the usual form and arrangement (figs. 1 and 2). The principal dimensions of the model were: span b of both

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*"Luftkräfte und Luftkraftmomente an einem Seeflugzeug auf dem Wasser." Z.F.M., August 28, 1933, pp. 442-446.

wings, 1.296 m (51.02 in.); maximum chord t of both wings, 0.187 m (7.36 in.); total wing area F, 0.4752 m² (5.12 sq.ft.). Other dimensions can be obtained approximately from figure 2.

2) Experimental arrangement.- The tests were made in the large Göttingen wind tunnel with the aid of the large 6-component balance (reference 2). Since, with the usual method of suspending the model, the balance stand can be turned laterally only $\pm 18^\circ$, a special arrangement of the model had to be adopted in this case, in order to obtain the desired lateral range of 0° to 360° exposure to the air stream. This was accomplished by suspending the model in the wind tunnel with the wings vertical, thus necessitating the vertical installation of the plate representing the surface of the water (fig. 2). In order to be able to bring the model into any desired position with reference to the plate, it was supported on a ball, so that the center of the ball coincided with the center of gravity of the model. The ball with the clamping device was mounted on a rod which in turn formed a part of the model support (figs. 2 and 3). The lateral adjustment was effected by means of a rotatable disk in the plate, in which the float models were embedded to the proper depth. The plate was hollow, so that the parts of the clamping device could be kept out of the air stream.

3) Testing.- The tests were for the purpose of determining three force components and three moment components, i.e., the six components requisite in a continuous process for the definite determination of the aerodynamic resultants in space. These six components were first determined for the system of axes fixed with respect to the wind tunnel and at an air velocity of about 30 m (98.4 ft.) per second. In order, however, to be able to consider the phenomena as presented to the seaplane pilot, the measured quantities were mathematically transformed so as to correspond to axes fixed with respect to the seaplane. The latter axes form a rectangular right-hand system, whose origin coincides with the center of gravity of the airplane and whose positive x-axis is parallel to the propeller axis and extends forward from the pilot. The quantities evaluated are the tangential force T, the lateral force S, the normal force N, the rolling moment M_{q_o}, the pitching moment M_{h_o}, and the yawing moment M_{s_o}. (The subscript

o indicates that the reference axes pass through the center of gravity.) The position of the model with reference to the plate was designated by the lateral angle τ, the pitching angle ϑ, and the banking angle φ. These forces, moments, and angles are shown in figure 4. Insofar as possible, the rules of the FALU for the standardization of aircraft notation were followed (reference 3). The tests include measurements at pitching angles ϑ of -1.5°, 3°, and 8° and at lateral angles τ of 0 to 180° or 360°. Moreover, a test was made in order to determine the velocity course near the plate without model (fig. 5). The test point is on the horizontal middle line of the plate at 28.5 percent of the plate length L (= 2.4 m = 7.87 ft.) from the leading edge. The vertical distance of the c.g. from the plate is h_o = 125 mm (4.92 in.).

III. RESULTS

The test results are represented nondimensionally. The force coefficients refer to the dynamic pressure q of the flow velocity and to the wing area F; the moment coefficients, also to the maximum wing chord t. (See table and figures 6, 7, and 8.) The abscissas represent the lateral angles $\tau = 0$ to 360°; the ordinates, the force, or moment coefficients. The plain curves correspond to the banking angle $\varphi = 0^\circ$; the dash curves to $\varphi = 5^\circ$. The effect of the suspension on the force and moment values was determined by a special test with the suspension alone, in which the model served as a "screen." Zero-point errors, due to imperfections in the model or in its adjustment during the tests, were not corrected. Figure 6 shows the course of the forces for the conditions investigated. The results of the moment measurements, as given in figures 7 and 8, contain much information for judging the behavior on the water. In a lateral current at an angle of about 60°, the rolling moment M_{qo} in the horizontal position of the model has approximately the same minimum value at all three of the pitching angles investigated. According to the definition there is a moment which tends to depress the starboard wing into the water so as to endanger the seaplane. For the smallest pitching angles tested, a second minimum of smaller value occurs in a lateral current at an angle of about 150°. The conditions are similar at lateral angles of $\tau > 180°$.* If the seaplane already has a lateral inclination in the direction of a right-hand or negative moment, then the dangerous moment increases about 37 percent for the maximum longitudinal inclination in a lateral wind of about 60°. The peak values recur at lateral angles above 180°. They are no longer very dangerous, however, because the depressed half of the wing is on the windward side. A current from the rear may become dangerous for the pitching moment M_{h_0}, especially at large positive longitudinal inclinations. The horizontal tail surfaces and the wing are then struck negatively above their trailing edges by the air current, so as to produce a tail-heavy pitching moment. In this case the floats offer but little resistance since, for technical reasons, they taper aft into slender tips. Herein lies another danger which, though it seldom eventuates, must always be considered in designing the floats. The yawing moment M_{s_0}, due to the lateral angle, is important for judging the operating characteristics of the seaplane on the water. The model investigated exhibited directional instability in all lateral air currents. The longitudinal and lateral inclinations had but little effect on the lateral moment.

IV. SUMMARY

The results of the 6-component tests of a seaplane model over a plate representing the surface of the water are reported and discussed. The tests were made at various longitudinal and lateral inclinations of the model in a lateral air current at 0 to 360°. The data can be useful to seaplane designers and pilots for judging the behavior of full-scale seaplanes on the water. This, however, represents only a modest beginning in obtaining experimental data for solving the problem of the mutual reactions of the water and air on the one hand and of the seaplane on the other hand. The experiments should be continued with seaplanes of other types. It would also be desirable to supplement the experiments under consideration by tests with various rudder deflections with the propeller running.

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*For the sake of clearness in the positions without lateral inclination, only the values for $\tau = 0$ to $180°$ are given. These values can be symmetrically supplemented for the region between 180 and 360°.

Translation by Drwight M. Miner,
National Advisory Committee for Aeronautics.

REFERENCES

1. Croseck, H.: Das Steuern der Seeflugzeuge auf dem Wasser. Werft-Reederei-Hafen, no. 19, 1932.

   Pabst, W.: Ziele und Wege der Schwimmwerksentwicklung von Seeflugzeugen. Werft-Reederei-Hafen, no. 11, 1933.

2. Betz, A.: Die Sechskomponenten-Waage des grossen Windkanals. Ergeb. Aero. Vers. Report IV, pp. 8 ff.

3. Blenk, H., and Mathias, G.: Zur Vereinheitlichung der Formelzeichen der Flugmechanik. Z.F.M., no. 22, 1932.

TABLE

$\tau°$		0&360	30	60	90	120	150	180	210	240	270	300	330
$\vartheta°$	$\varphi°$						c_t values						
-1.5	0	0.0345	0.0310	-0.0020	-0.0370	-0.0180	-0.0450	-0.0525					
-1.5	+5	0.0375	0.0330	0.0130	-0.0250	-0.0040	-0.0380	-0.0535	-0.0585	-0.0255	-0.0395	-0.0015	0.0390
+3.0	0	0.0295	0.0220	-0.0140	-0.0400	-0.0280	-0.0590	-0.0590					
+3.0	+5	0.0305	0.0090	-0.0125	-0.0295	-0.0225	-0.0195	-0.0595	-0.0550	-0.0460	-0.0320	-0.0075	0.0295
+8.0	0	-0.0120	-0.0220	-0.0110	-0.0380	-0.0330	-0.0465	-0.0490					
+8.0	+5	-0.0190	-0.0360	-0.0125	-0.0185	-0.0175	-0.0525	-0.0520	-0.0425	-0.0300	-0.0245	-0.0160	-0.0055
							c_s values						
-1.5	0	-0.0045	-0.181	-0.289	-0.284	-0.273	-0.175	0					
-1.5	+5	-0.0135	-0.226	-0.298	-0.292	-0.305	-0.230	-0.0160	0.199	0.279	0.301	0.308	0.188
+3.0	0	0	-0.173	-0.295	-0.294	-0.276	-0.189	0.0010					
+3.0	+5	-0.0650	-0.250	-0.303	-0.288	-0.298	-0.227	0.0565	0.229	0.278	0.302	0.306	0.163
+8.0	0	0	-0.170	-0.269	-0.288	-0.264	-0.183	0.0110					
+8.0	+5	-0.104	-0.271	-0.305	-0.288	-0.287	-0.136	0.115	0.247	0.287	0.298	0.262	0.104
							c_n values						
-1.5	0	0.099	0.148	0.0895	0.0655	0.174	0.162	0.167					
-1.5	+5	0.0880	0.238	0.137	0.0400	0.229	0.300	0.182	0.0670	0.101	0.0515	0.0020	0.037
+3.0	0	0.444	0.433	0.250	0.0805	0.0840	-0.149	-0.350					
+3.0	+5	0.389	0.482	0.208	0.0425	0.167	0.0070	-0.276	-0.210	0.0250	0.0530	0.0730	0.250
+8.0	0	0.691	0.634	0.248	0.0700	-0.0075	-0.431	-0.694					
+8.0	+5	0.712	0.676	0.288	0.0220	0.0510	-0.355	-0.694	-0.492	-0.0880	0.0460	0.193	0.557
							$c_{m_{qo}}$ values						
-1.5	0	-0.0375	-0.161	-0.215	-0.126	-0.176	-0.205	0.074					
-1.5	+5	-0.0440	-0.170	-0.240	-0.242	-0.269	-0.179	0.0885	0.196	0.0940	0.0650	0.115	0.0660
+3.0	0	-0.0460	-0.156	-0.222	-0.121	-0.128	-0.105	0.0380					
+3.0	+5	-0.0055	-0.149	-0.264	-0.240	-0.241	-0.157	-0.0350	0.0590	0.0195	0.0610	0.157	0.115
+8.0	0	-0.0580	-0.176	-0.240	-0.128	-0.0615	-0.0290	0.0215					
+8.0	+5	-0.0560	-0.213	-0.330	-0.209	-0.143	-0.0895	-0.0310	-0.0880	-0.0185	0.0700	0.160	0.0945
							$c_{m_{ho}}$ values						
-1.5	0	-0.0345	0.0210	-0.0215	-0.0070	0.0885	0.0780	0.160					
-1.5	+5	-0.0415	0.0425	0.0125	0.0390	0.186	0.201	0.160	0.0105	0.0080	-0.0285	-0.0630	-0.0120
+3.0	0	0.0490	0.0930	0.0025	-0.0095	0.0375	-0.138	-0.302					
+3.0	+5	0.0265	0.0890	0.0140	0.0265	0.141	0.0005	-	-0.207	-0.0575	-0.0335	-0.0665	0.0255
+8.0	0	0.131	0.116	-0.0065	-0.0315	-0.0305	-0.368	-0.578					
+8.0	+5	0.139	0.140	0.0640	-0.0035	0.0420	-0.277	-0.585	-0.455	-0.147	-0.0360	-0.0155	0.0830
							$c_{m_{so}}$ values						
-1.5	0	0.0085	0.113	0.141	0.270	0.335	0.247	-0.0085					
-1.5	+5	0.0105	0.112	0.164	0.264	0.318	0.237	-0.0165	-0.284	-0.361	-0.278	-0.185	-0.118
+3.0	0	-0.0015	0.0915	0.135	0.257	0.339	0.244	-0.0030					
+3.0	+5	0.0025	0.0910	0.148	0.246	0.326	-	-0.0080	-0.256	-0.348	-0.265	-0.169	-0.109
+8.0	0	0.0035	0.0575	0.128	0.221	0.292	0.223	-0.0100					
+8.0	+5	-0.0055	0.0705	0.120	0.250	0.320	0.271	0.0105	-0.228	-0.337	-0.250	-0.172	-0.0885

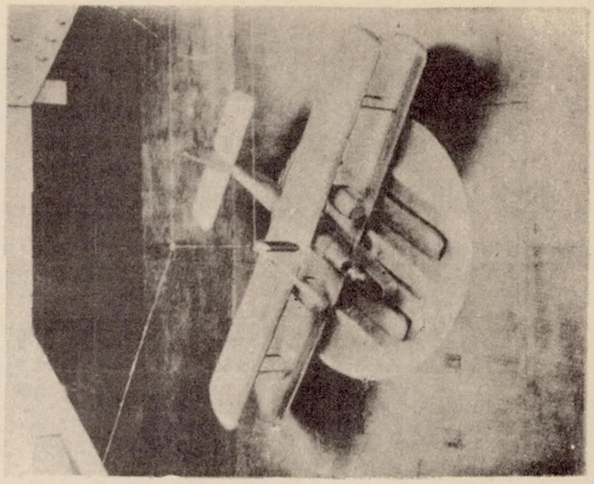

Figure 1.- Model suspended in wind tunnel over plate representing surface of water.

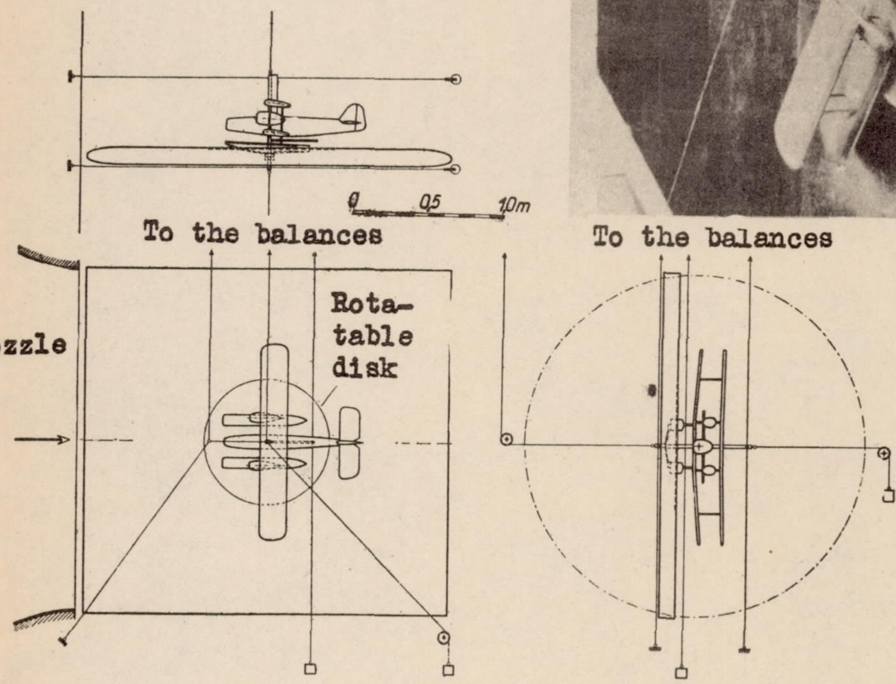

Figure 2.- Experimental arrangement.

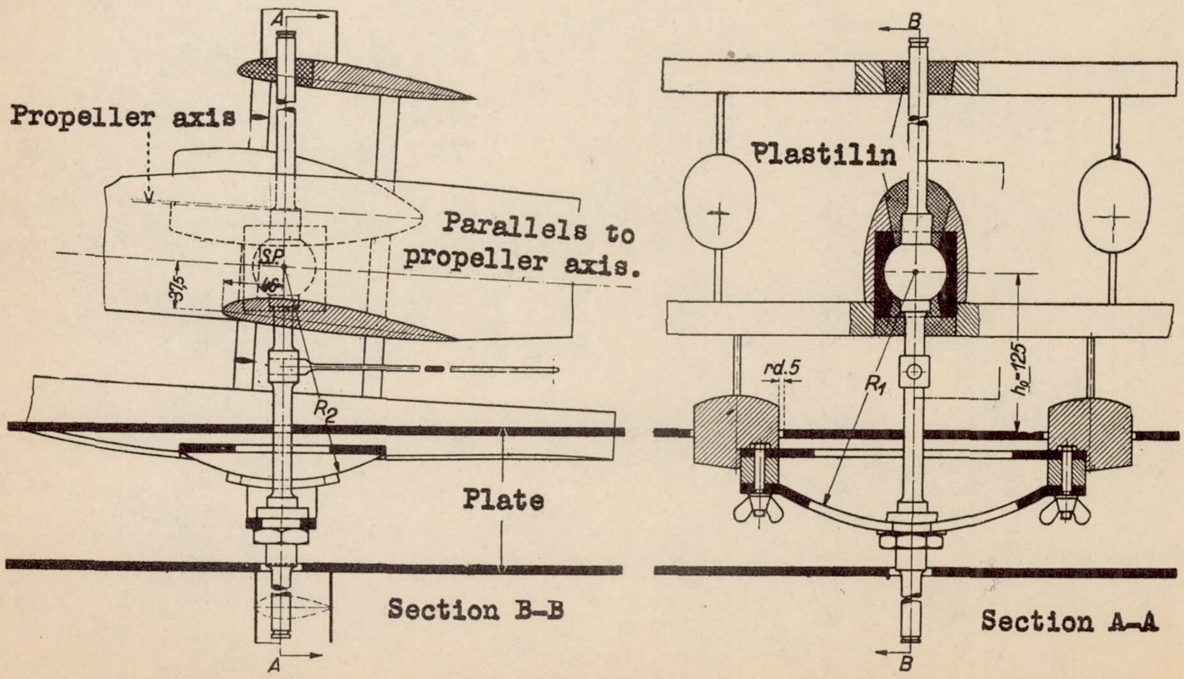

Figure 3.- Device for securing model to suspension rod.

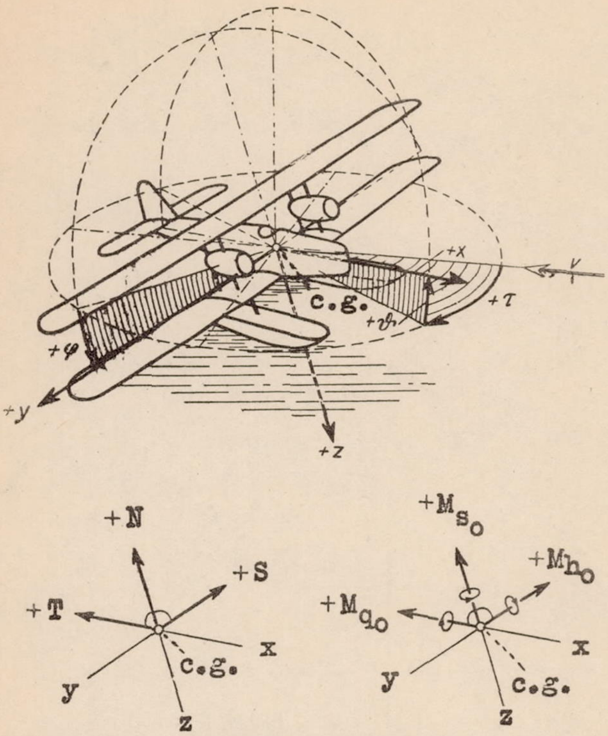

Figure 4.- Definition diagrams for system of axes fixed with reference to airplane; forces, moments and angles.

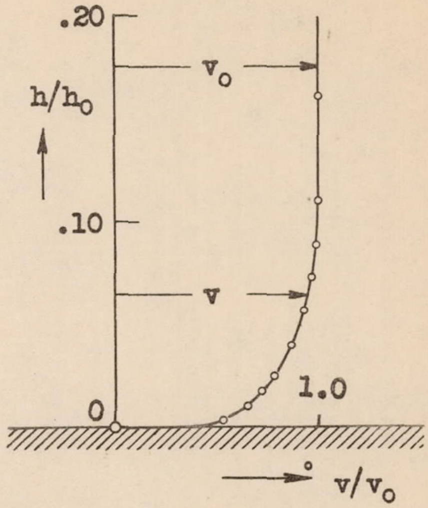

Figure 5.- Velocity curve in vicinity of plate, without model.

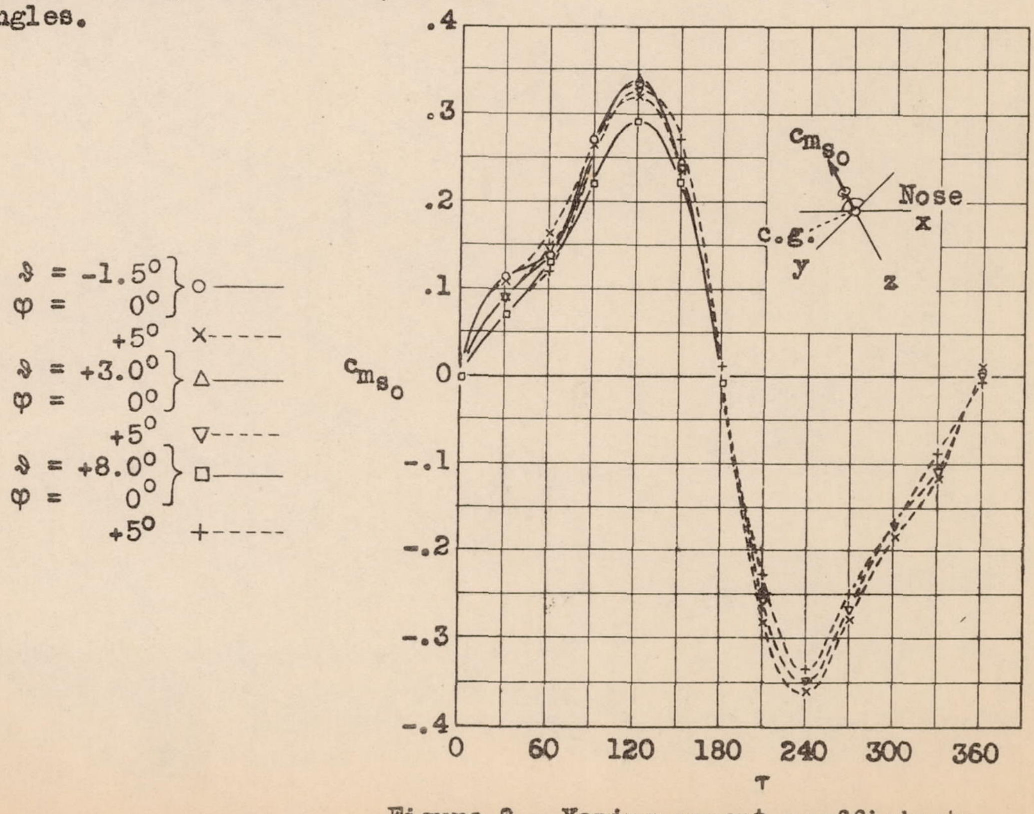

Figure 8.- Yawing-moment coefficients.

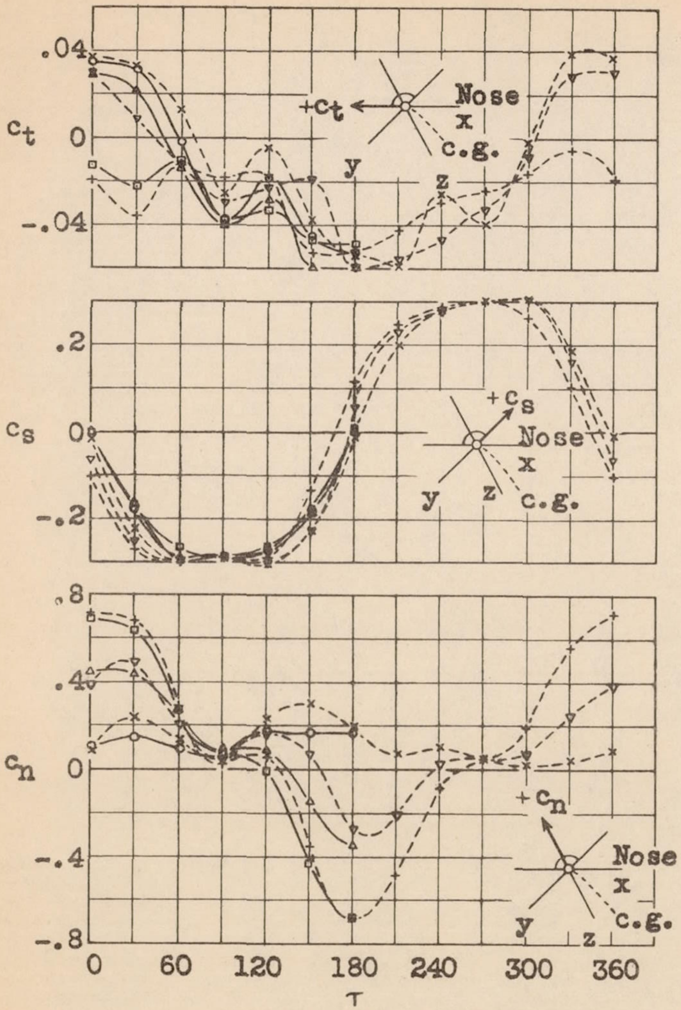

Figure 6.- Force coefficients.

ϑ = -1.5° ; φ = 0° ○———
+5° ×- - - - -
ϑ = +3.0° ; φ = 0° △———
+5° ▽- - - - -
ϑ = +8.0° ; φ = 0° □———
+5° +- - - - -

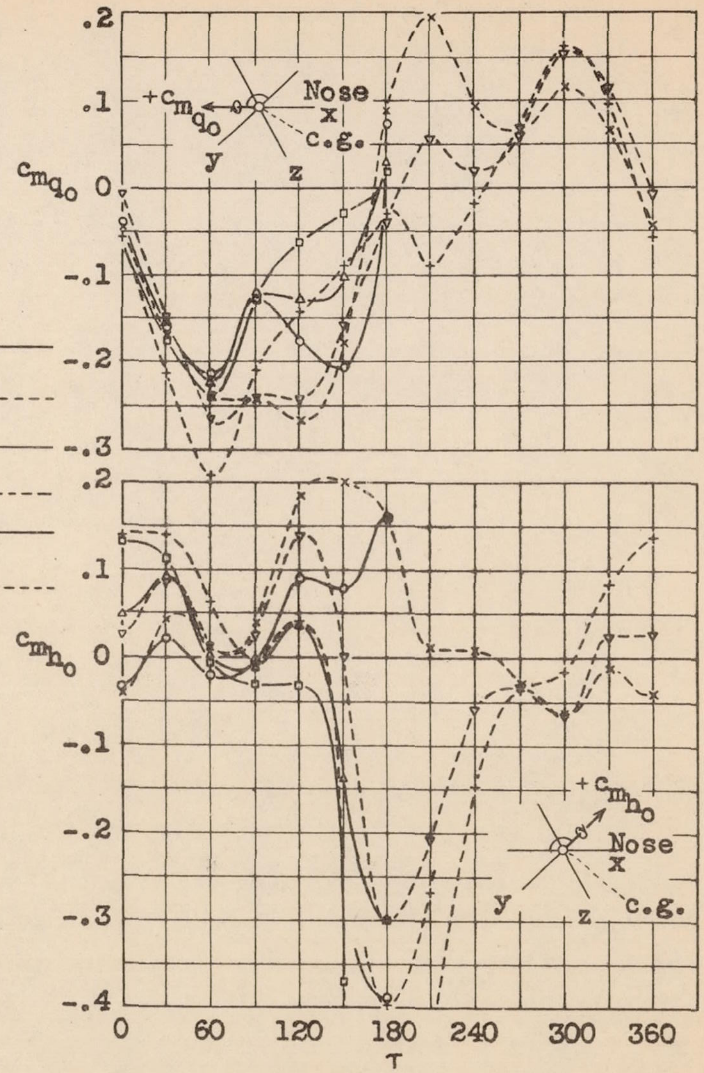

Figure 7.- Coefficients of rolling and pitching moments.